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TRANSPORTATION RESEARCH COMMAND

FORT EUSTIS, VIRGINIA

CRASH INJURY EVALUATION

CREW SEAT DESIGN CRITERIA FOR ARMY AIRCRAFT

February 1963

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TRECOM Technical Report 63-4

prepared by :

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It has long been known that the G-load factors specified in military specifications applicable to the design and manufacture of crew seats utilized in Army aircraft are not commensurate with either human tolerance to force or the crash forces experienced in survivable-type accidents.

Until recently, very little was known about the kinematics of an aircraft crash. A series of dynamic crash tests conducted by AvCIR over the past two years, together with a thorough review of the literature relative to this subject, has provided data upon which to base recommendations for changes to existing military specifications as they relate to crashworthiness aspects of the aircraft occupant tiedown chain.

Contained herein are the results of a careful analysis of crew seat deficiencies. Criteria are expressed in terminology which is meaningful to design engineers. Utilization of the information presented in this report will not produce the ultimate in crew seat design; it will, however, produce a seat that is representative of the current state of the art and will significantly reduce the incidence of needless injury and death attributable to crew seat failure in survivable-type Army aircraft accidents.

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CREW SEAT DESIGN CRITERIA FOR ARMY AIRCRAFT

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ILLUSTRATIONS (Cont'd.)

ILLUSTRATIONS

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SUMMARY

Strength requirements set forth in military specifications governing the design and fabrication of nonejection-type crew seats currently utilized in Army aircraft were analyzed. The analysis was made in light of accident experience with this seat, human tolerance as presently known, and accelerations and forces which may be anticipated in accidents involving Army aircraft.

The analysis revealed that the strength requirements quoted in current military specifications are considerably lower than (1) those which would be dictated by the upper limit of accelerations which can be tolerated by the occupants of the seats and (2) the accelerations and forces that are associated with Army aircraft accidents. This substantiates the observation by the Army that these seats fail under relatively moderate accident conditions, thus subjecting the occupant to further hazards, especially in increased contact injuries.

On the basis of the detailed examination of current specifications, human tolerance, and impact acceleration data, it is recommended that the crew seat specifications be revised and that dynamic load factors of 25G for 0.20 second plus 45G for 0.10 second, measured in the pelvic region of a suitable anthropomorphic dummy, be adopted for crew seat design in the longitudinal and lateral directions, and 25G for 0.20 second for the vertical direction. In addition, an energy absorption capability must be incorporated into the seat system to reduce the vertical accelerations, which will frequently exceed 25G, to a tolerable level.

CONCLUSIONS

Based upon the information contained in this report, it is concluded that:

1. Crew seats built to specification MIL-S-5822 fail under relatively moderate impact conditions, exposing the occupants to unnecessary injury or death.

2. The most significant deficiencies in the above-cited specification are the design load factors. They are incompatible with known human tolerance to abrupt accelerations and with impact acceleration levels which may be expected in potentially survivable aircraft accidents.

3. Revision of the specification, with particular emphasis on increasing the design load factors as recommended in this report, will reduce the incidence of seat failures and will provide protection for the occupants commensurate with human tolerance to acceleration and consistent with the strength and energy-absorbing characteristics of modern Army aircraft.

RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. Applicable military crew seat and related specifications be revised to provide increased occupant protection in potentially survivable crashes.

2. All revisions of the applicable specifications be based upon the following design load factors:

   a. Longitudinal and Lateral Design Loads: The seat, its support system, and the occupant restraint system should, individually and in combination, be capable of maintaining 25G for 0.20 second and 45G for 0.10 second in the pelvic region of a suitable anthropomorphic dummy having a weight and mass distribution of that of the heaviest occupant expected. Progressive plastic deformation of the seat and restraint system is permissible provided (1) complete failure and (2) subsequent injurious situations do not occur.

   b. Vertical (Headward) Design Loads: The seat, its support system, and the occupant restraint system should, in combination, be capable of continuously maintaining 25G $\pm$5G, in the pelvic region of the dummy described in (a) above, while deforming through at least 12 inches of vertical travel with respect to the airframe and, where possible, up to 15 inches or more of vertical travel.

EVALUATION OF CREW SEAT SPECIFICATIONS

INTRODUCTION

Emphasis in aircraft accident investigation, until recent years, was placed on finding the cause of the accident. Very little effort was expended and few organizations were interested in the crash injury aspects of aviation safety. In recent years, however, increased interest has been indicated and a considerable amount of effort is being expended in improving the design of aircraft structure and components in an attempt to reduce the exposure of aircraft occupants to unnecessary injury or death when involved in aircraft accidents. The purpose is to increase the rate of survival in those accidents which will occur. This increased interest in improving the survival rate has been particularly true in the Army aviation program.

The objective of this study is (1) to evaluate the requirements set forth in applicable crew seat specifications in the light of human tolerance to abrupt acceleration, as known at this time, and the accelerations and forces which may be anticipated in accidents involving Army aircraft, particularly helicopters, and (2) to develop design criteria which may be used in the revision and improvement of applicable specifications.

ANALYSIS OF SPECIFICATION REQUIREMENTS

Accident experience has shown that seats built to Specification MIL-S-5822, 12 August 1957, fail structurally when subjected to moderate crash forces which leave the environmental structure completely or substantially intact. This indicates that the design requirements set forth in the specifications are not compatible with the loads experienced in potentially survivable accidents.

Figure 1 depicts a crew seat of current design. The specification requires that the crew seat be subjected to, and withstand, the ultimate static loads given in Table 1. For convenience, the figures have been converted into G units which are based on a 200-pound occupant.

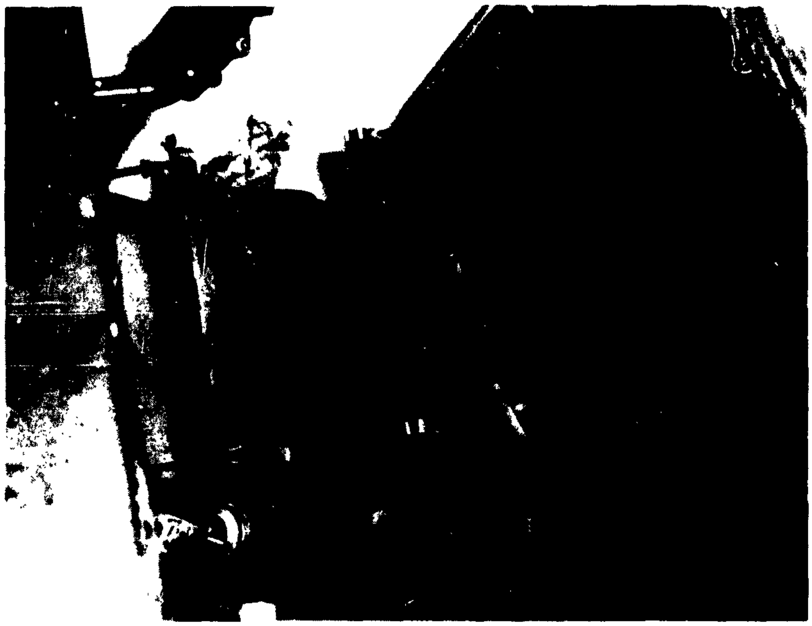


Figure 2. Pilot's Seat Failure in Accident A.
The arrows depict points of failure of the seat support members.

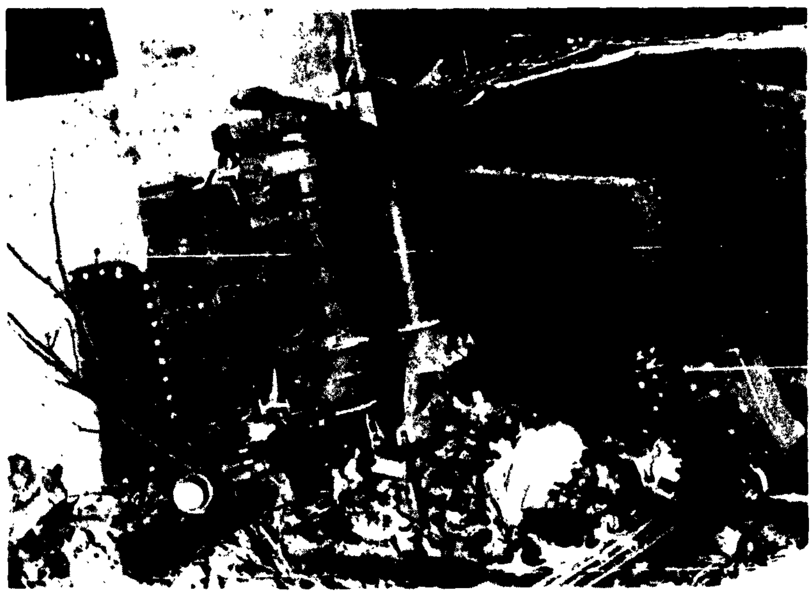


Figure 3. Copilot's Seat Failure in Accident A.
The four seat support members (arrows) of the copilot's seat failed due to side load.

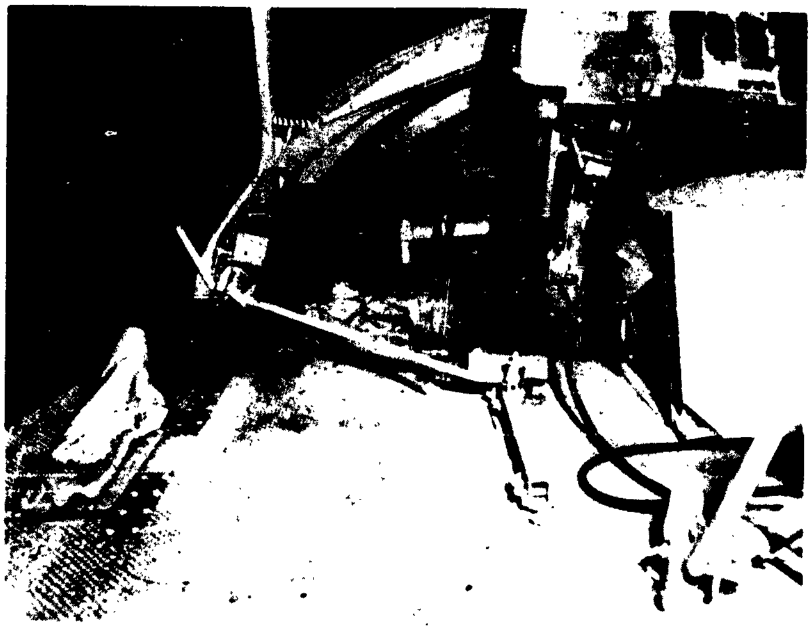


Figure 4. Left Seat Failure in Accident B.
The right rear leg tore free from the carriage while the left rear leg ripped the track from the floor, permitting the seat to pivot forward. The front attachments were torn free by rescue personnel.

Figure 5. Right Seat Failure in Accident B.
The arrows denote the failures in the leg castings on the right seat.

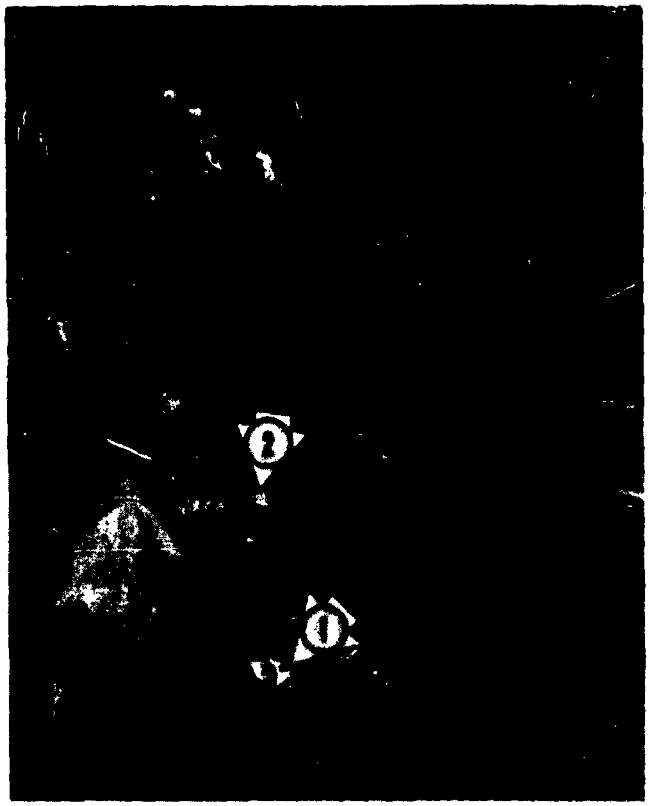


Figure 6. Rear View of the Seat Failure in Accident C.
The rear attachment failed at the casting (arrow 1) while the front failure occurred at a drilled point in the front cross-tube (arrow 2).

HUMAN TOLERANCE AND IMPACT ACCELERATION

As shown in the previous section of this report, the military crew seats presently utilized in Army aircraft and built in accordance with Specification MIL-S-5822 have been subject to gross failure, even under moderate impact conditions. Examination of the specifications governing the design and construction of these seats strongly suggests that the reason for these failures is that the load factors to which the seats are designed are unrealistic and incompatible with the apparent crash resistance of both the structure of the occupiable sections of the aircraft and the human anatomy itself.

Since the integrity of occupant support systems is the most critical factor in preventing injuries or fatalities in a potentially survivable accident, it would appear logical to design the seats and occupant restraint systems to load factors which parallel those of the basic structure and approach the human tolerance to accelerations.

Based upon the foregoing, a comprehensive study has been made of the available information and data on these two subjects. Following is a discussion and analysis of the more important factors.

HUMAN TOLERANCE TO ABRUPT ACCELERATION

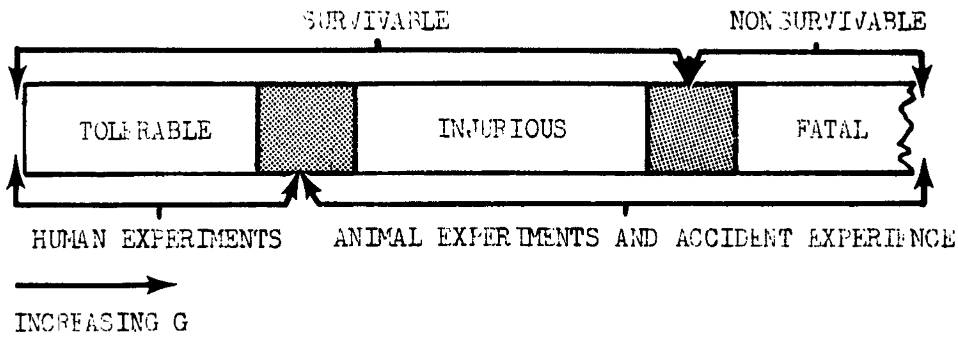
With respect to tolerance by the human body, accelerative stresses are usually divided into three categories, as follows:

1. Tolerable limits. These are the acceleration limits, as set by voluntary subjects, of voluntary tolerance in experimental work and as deduced from accident experience. The subject is not incapacitated, although minor trauma, including abrasions, etc., not requiring medical care is acceptable if it does not impede an immediate escape attempt.

2. Injurious limits. These are associated with moderate or severe trauma and/or incapacitation, but with survival ensured with prompt medical care. The subject may be unable to extricate himself from the wreckage in time to avoid death (by drowning or fire).

3. Fatal limits. These are based upon nonsurvivable trauma as a direct or indirect result of excessive force application upon the body.

Diagramatically, these limits can be presented as follows. The shaded areas indicate the transition zones.



It should be noted that each type of restraint system has its own tolerable-injurious-fatal pattern depending upon its effectiveness as a body support. It would appear that the design target for a given restraint system should extend beyond the tolerable range to ensure maximum survivability under the most adverse conditions; that is, some injury should be considered acceptable.

MAGNITUDE AND DURATION

Acceleration experiments have demonstrated that human tolerance to acceleration decreases with an increase in either the magnitude and/or the duration of the acceleration pulse, as indicated in the curves shown in Figures 7 and 8.[7, 11]

The data presented in Figure 7 are based on tolerance to acceleration perpendicular to the spine (transverse G). The lower curve in the figure indicates that the tolerable limit is about 45G for a period up to .044 second, at which point the magnitude decreases as the time of exposure increases. An acceleration of only about 9G was voluntarily sustained for a period of 2 seconds. In obtaining the data for Figure 7, the subjects were restrained by seat belt, thigh straps, shoulder harness, and chest straps. None of the subjects was injured or debilitated. The upper limits for moderate injury are shown by the dashed line in the figure, which forms the boundary between moderate and severe injury areas. *

Figure 8 presents similar information on human tolerance to acceleration parallel to the spine (head-to-foot). Body support used in developing the data shown in Figure 8 consisted of seat belt and shoulder harness. The data indicate that accelerations of 16G for a pulse duration of .04 second were tolerated without shock or injury. The tolerance then decreases to approximately 10G when the duration is increased to .1 second and further decreases with longer durations. It will be noted in Figure 8 that the limits upon which present ejection seats are designed lie in the area of moderate injury. *

DIRECTION OF FORCE APPLICATION (BODY ORIENTATION)

In a discussion of the effects of magnitude and duration of acceleration, it becomes readily apparent that the direction of force application plays a significant role in human G tolerance to abrupt acceleration.

Examination of the curves in Figures 7 and 8 shows that this tolerance is considerably greater in a direction perpendicular to the spine (transverse G) than in a direction parallel to the spine. Two of the reasons for this difference in tolerance are:

First, the skeletal configuration and mass distribution of the human body are such that loads resulting from vertical accelerations cannot be as readily distributed over a restraint system as can loads resulting from horizontal accelerations. Therefore, vertical loads generally result in a greater stress per unit area than transverse loads.

* It must be noted that the data shown in Figures 7 and 8 were obtained under conditions involving only one degree of freedom. Under actual accident conditions, accelerations in all three coordinate directions may be expected to occur either simultaneously or with random time phasing. Under such conditions, the tolerances shown in the figure would probably be reduced. Further research is needed to determine the effects of simultaneous or random phased accelerations in the lateral, longitudinal, and vertical directions.

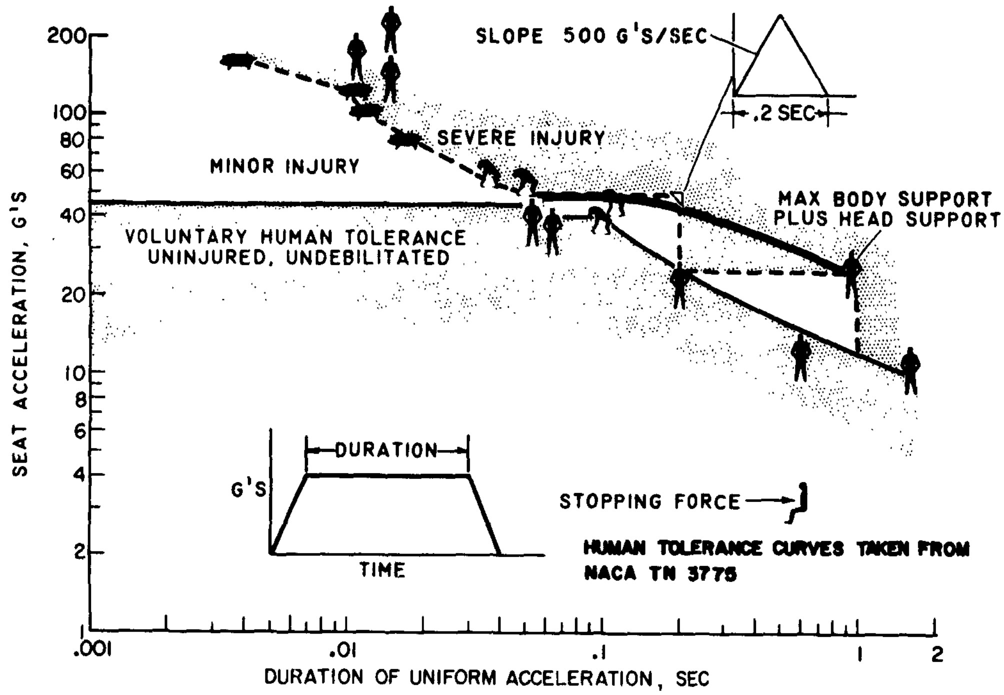


Figure 7. Tolerance to Acceleration Perpendicular to Spine With Maximum Body Support.

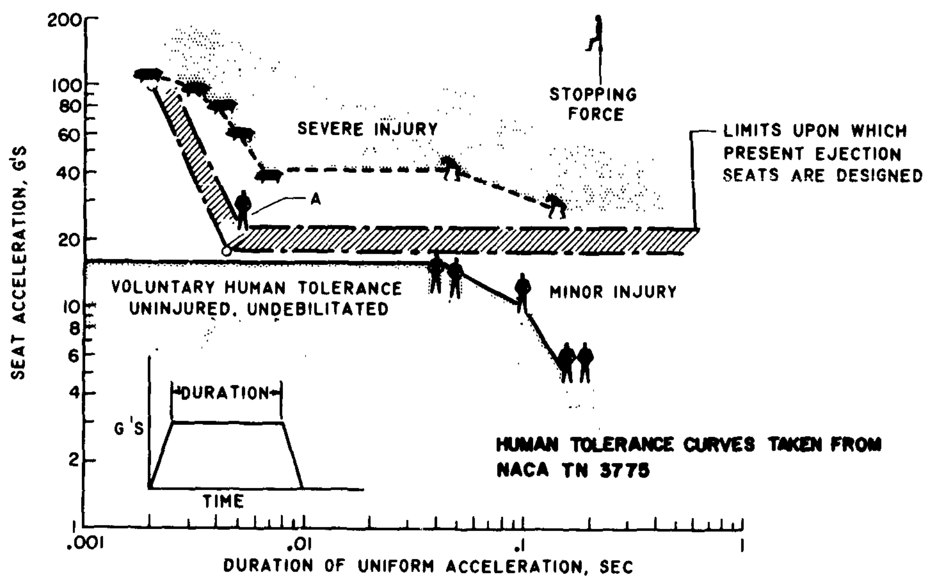


Figure 8. Tolerance to Acceleration Parallel to Spine With Lap Belt and Shoulder Harness.

Second, the viscera have more freedom of movement (displacement) in the vertical plane or long axis of the body than in the horizontal plane. Consequently, impact parallel to the spine causes more strain on the suspension system of the viscera than an equivalent impact perpendicular to the spine.

The variation in human G tolerance with respect to body orientation is best demonstrated by a comparison of ejection-seat and free-fall experience. It is generally accepted that for minor or no injury, the maximum tolerance to vertical acceleration for a properly seated and restrained subject is 20G, acting for periods up to 0.1 second. During ejection-seat experiments, compression fractures of the vertebrae have been produced at the 26G level. In a study of free-fall accidents, it was concluded that the human body has withstood an estimated 200G (for very short intervals) during which the force acted transverse to the long axis of the body.[4] This so-called miraculous survival in free-fall accidents demonstrates the body's high tolerance to transverse deceleration when properly supported in a prone, supine, or sideways landing on sand or ductile sheet-metal structure.

METHOD OF BODY RESTRAINT

The purpose of a restraint system is to enable an aircraft occupant to participate in the acceleration of his environment. Experimental research in this area reveals that, usually, the more rigid the link between the occupant and vehicle, the higher the tolerance limit.[18] The limitations associated with the various types of restraint systems are governed by the following factors:

1. Force Distribution. The greater the contact area between the body and the restraint system, the less the force experienced per unit area. This is illustrated in the following chart, which is based upon a 10G deceleration and a body weight of 170 pounds.

	Approximate Contact Area (Sq. In.)	Approximate Load (P. S. I.)
2-inch seat belt	40	42
3-inch seat belt	60	28
Aft-facing seat	210	8

2. Residual Freedom of Movement. Unrestrained body components tend to displace in a direction opposite that of the applied crash force due to the inherent inertia of the unrestrained parts. The extent of the displacement is determined by the arrangement of the restraint system. When the upper body is free to move, the impact tolerance can be seriously impaired. For example, in a situation where only a seat belt is used with a forward-facing seat, the upper torso will rotate forward over the belt during a rearward acceleration of the seat. This action brings the spinal column into alignment with the applied force and can actually result in tension in the upper torso. Further complications may be caused by the whipping action of the head and neck when the chest is suddenly arrested by contact with the thighs.[6]

SEAT BELT RESTRAINT

Since the tolerable and injurious G limits increase with increased distribution of the accelerative force over the entire skeleton, and since the seat belt in forward-facing seats constitutes a minimum of body support, it follows that this popular restraint system is associated with the lowest tolerable, injurious, and lethal G limits.[3] Although exact information is not available on the tolerance limits associated with seat belt restraint only, the following estimates are found in the literature:

Pinkel	-	17G at 0.26 second	---Ref. 12
Pesman	-	15G	---Ref. 11
Von Gierke	-	10-20G	---Ref. 7

When restrained by seat belt only, as is customary in most light aircraft and in the transports, the occupant's body has a tendency to bend around the seat belt during rearward acceleration. This is commonly referred to as "jackknifing" (Figure 9). If this bending of the body occurs at its natural joint, the hips, the strain on the spine will be nominal. When bending occurs at a higher level, such as in the upper lumbar or lower thoracic region, due to improperly installed or used seat belts, spinal injuries may result from the flexing of the spine.

A review of the inherent limitations of seat belt protection in aircraft accidents is not complete without considering the practical limitations imposed by environmental factors. The seating configuration in most aircraft is such that the occupants seldom have an unobstructed path for their flailing extremities and upper torso. Although environmental structure within striking distance can be made noninjurious to a certain extent, in many cases the protection offered by seat belt restraint is limited not only by the ultimate strength of the belt but also by the injurious aspects of the occupant's surroundings.

A recent AvCIR study[3] indicates that 25G (occupant weight, 200 pounds) is a practical design limit for a system using seat belt only. Depending upon the physical condition of the occupant and the manner of belt adjustment, various degrees of decelerative injuries may be expected at 25G; however, with survival at stake, this risk is preferable to the unpredictable exposure of an occupant who becomes a projectile after restraint system failure and is brought to a haphazard stop inside or outside the wreckage.

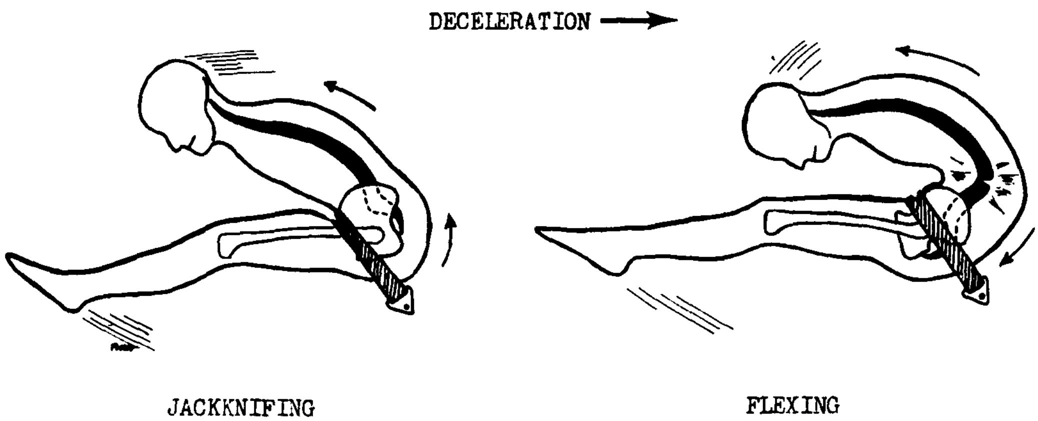


Figure 9. Body Jackknifing and Flexing.

SEAT BELT AND SHOULDER HARNESS

The added support obtained from a properly installed and utilized shoulder harness prevents the rotary motion of the upper torso, provides better load distribution, and reduces the dynamic response of the body, as a whole, to accelerative forces. Consequently, the human tolerance to acceleration will be higher under these circumstances than those in which seat belt only is used.

Although adequate upper torso restraint by means of a shoulder harness (special research model) was one of the prerequisites for Stapp's 40G sled run, it is interesting to note his comments or the standard USAF shoulder harness and seat belt. The standard USAF shoulder harness and seat belt consisted of 1-3/4-inch shoulder straps and a 3-inch-wide nylon seat belt with special 40G buckle and fittings.[19] The following is a quotation from Reference 19:

> "Tests with different harness configurations brought out the following:
>
> 1. The standard USAF harness shoulder strap and lap belt combination was unstable and inadequate with uneven application of force due to the following sequence.
>
>   A. The head and shoulders coming forward, stretching the shoulder straps and elevating the lap belt to the solar plexus level, above the center of gravity of the seated subject.
>
>   B. The pelvic girdle and lower extremities then slid forward without restraint until the trunk draped around the lap belt. This resulted in sudden pressure to the epigastrium and rib margins that was not tolerated by any subject above the 17G average applied acceleration. This agrees well with the findings of Bierman whose subjects could not tolerate more than 2, 600 lbs. with the same harness.
>
> 2. Using strain gages on the right shoulder strap and right lap belt, it was found that varying the relative tension of lap straps and shoulder straps varied the ratio of pull measured on the straps. A tight lap belt and relatively looser shoulder straps was the subjectively less irritating arrangement."
>
> "The research model harness with 3-inch nylon throughout and the inverted V leg straps held the trunk in good position and distributed the impact load much better, with subjects repeatedly taking tests at 35G average deceleration and higher with no more than transient discomfort."

In conclusion, it may be stated that the advantage of the standard shoulder harness is that it not only improves tolerance to acceleration but also prevents upper torso and head contact with the surrounding structure, this being the predominant cause of fatal and serious crash injuries.

MAXIMUM BODY SUPPORT

Although maximum body support during transverse acceleration is usually limited to experimental work, it adequately serves to illustrate the effect of body restraint upon the human tolerance to accelerative forces. In this respect, it is interesting to note that maximum tolerance in forward-facing seats is always associated with the use of thigh straps or inverted V straps in combination with seat belt and shoulder harness. This prevents tipping of the pelvis and raising up of the seat belt to the upper abdomen and lower rib cage and ensures that the major portion of the accelerating force is applied to the pelvic girdle. With this type of restraint, 40G has been sustained for 0.12 second without irreversible injury, and overshooting of the subject to 60G for .02 second has been tolerated as well.[19]

The use of maximum body support has been a major factor in raising the impact tolerance of the capsule occupants. In most cases, the force is applied transversely by placing the subject in a supine position. A contoured couch molded to fit the individual provides optimum body support. The following impact accelerations were tolerated, for short durations,* by human subjects in a capsule configuration (in separate tests).[9]

	Transverse	Lateral	Vertical
Capsule	86.6G	19.5G	32.4G
Subject	126.5G	65.0G	74.6G

SEAT DESIGN CRITERIA BASED UPON HUMAN TOLERANCE

Based upon the foregoing discussion, it is concluded that human tolerance to abrupt acceleration, from a practical point of view, is dependent upon a variety of factors. The most important controllable factor is the orientation and distribution of the restraint system and inertia forces over the body. Survival of abrupt accelerations in aircraft accidents will, therefore, largely depend upon the type and strength of the seat, the orientation of the seat, and the type of restraint system utilized.

A series of hypothetical curves has been prepared to show how the human tolerance probably varies when subjected to abrupt transverse

* Exact durations not published. Total change in velocity was of the order of 30 feet per second.

acceleration under a variety of seat and restraint system combinations presently in use (Figure 10). The relative positions of these curves were deduced from the limited experimental data available. They illustrate qualitatively the relation between restraint system and tolerance; but, because of the lack of sufficient data points, they cannot be considered sufficiently accurate for design purposes, except for the restraint system comprising (1) seat belt and (2) seat belt with shoulder harness and thigh straps. This would, however, suggest an intermediate position for the curve for a "seat belt plus shoulder harness" restraint system as indicated in Figure 10.

The final determination of seat design criteria must be based on a number of compromises; however, a careful selection of design points from the currently available tolerance and crash test data, with allowances for the seating configuration and restraint system desired by the user, will provide realistic design values. Values have been selected below for the three principal directions of motion and appear to offer realistic protection for occupants of military crew seats:

> Longitudinal and Lateral Strength Requirements: For a crew seat installation in which seat belts will be the only form of restraint used, the seat should thus be designed to withstand both longitudinal and lateral accelerations of 25-30G (when occupied by a 200-pound man) for a duration of 0.2 second* without gross failure. Progressive or controlled deformation would be acceptable.
>
> If consideration is given to the use of shoulder harness with the seat belt, and this is strongly recommended, the tolerance of the occupant to acceleration is increased. To assure seat and restraint system integrity compatible with human tolerance in this condition, the seat and restraint system must be designed to a higher set of load factors than presently employed. Again plotting a midpoint in the injurious zone for a seat belt/shoulder harness restraint system in Figure 10, the load factor should be somewhere between 40-50G; for a duration of 0.1 second, with the added capability of maintaining 25G for 0.2 second.

*25G for 0.2 second corresponds to a change in velocity of 160 feet per second, or approximately 110 miles per hour.

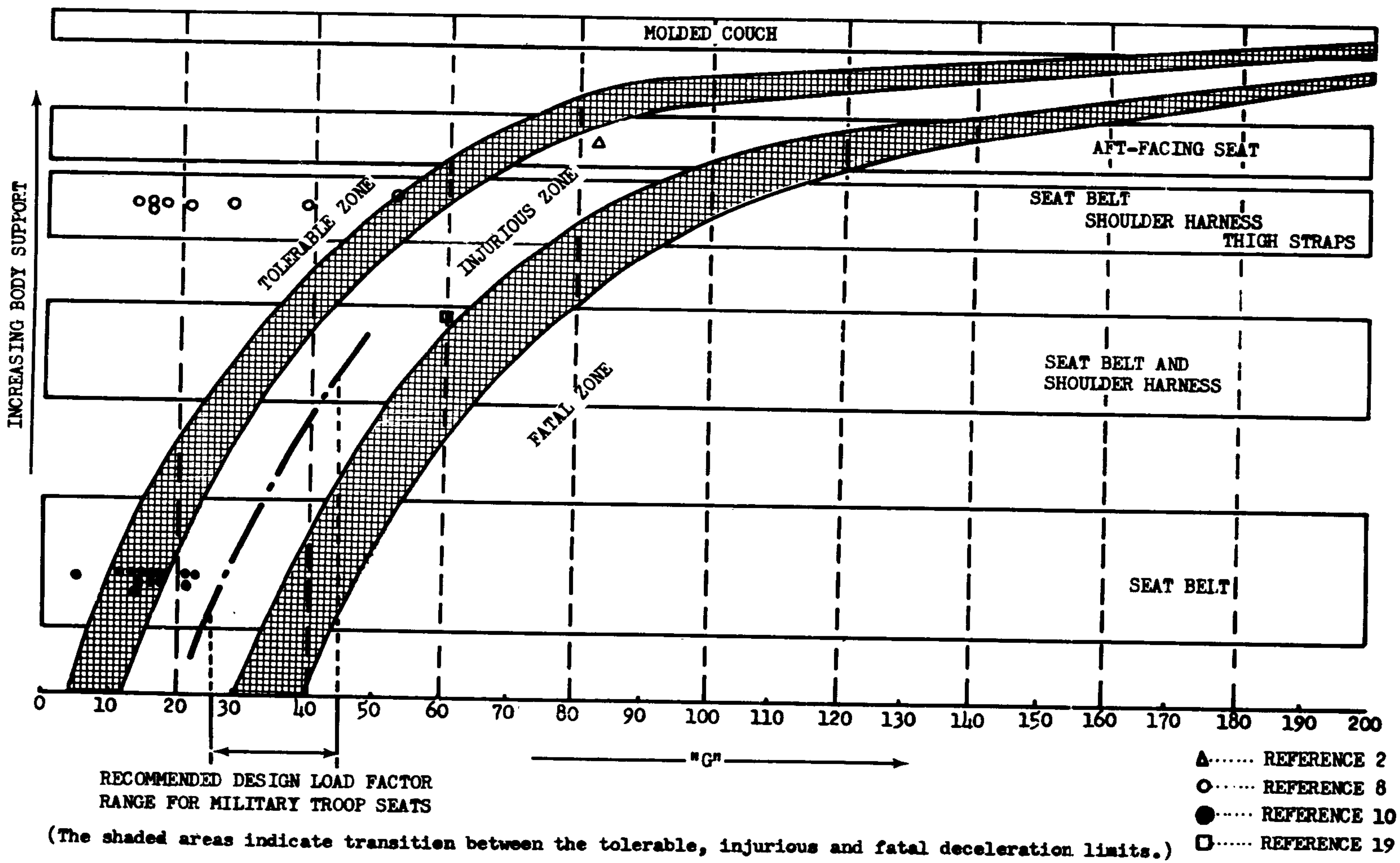


Figure 10. Hypothetical Correlation of Restraint Systems and Human Tolerance to Abrupt Transverse Deceleration for Durations from .001 to 0.10 Second.

Vertical Strength Requirements: Human tolerance to acceleration parallel to the spine is fairly well defined and less affected by variations in the seat restraint systems.

If it is again assumed that some injury is acceptable, it would appear that a reasonable compromise for vertical load factors would be 25G for a period of 0.10 second. (See Figure 8.)

It must be pointed out, however, that vertical accelerations in rotary-wing aircraft accidents generally exceed 25G,[20] as will be shown in the next section of the report. In order to prevent the vertical acceleration of the occupant of rotary-wing aircraft accidents from exceeding the above-recommended 25G, improved seat suspension systems and energy absorption techniques will be required. Further requirements for the seat with respect to the vertical acceleration inputs must thus be met. These requirements will be developed more fully in a later section.

In summary, seat and restraint systems designed to load factors of 25G in the three principal directions will provide support up to the tolerance levels of the human body when restrained by seat belt only. If a shoulder harness is used in combination with the seat belt, then the longitudinal and lateral limits should be increased to 45G for .1 second.

IMPACT ACCELERATION DATA

The purpose of this discussion is to determine whether the seat design load factors selected on the basis of human tolerance are compatible with impact accelerations which may be anticipated in potentially survivable accidents of both fixed-wing and rotary-wing aircraft, i.e., in which the occupiable area of the aircraft remains reasonably intact. Such an accident may be considered to be potentially survivable. Calculation of the exact forces and accelerations experienced in actual accidents is not possible because of the complexity of the structure of the aircraft. Experimental crash tests of both fixed-wing and rotary-wing aircraft have been conducted and, while limited in scope and number, provide useful data for determining accelerative loads under actual accident conditions.

The data from twenty experimental crash tests were analyzed. Fifteen of the tests were made by NACA using fixed-wing aircraft. Five of the tests were made by AvCIR using helicopters.

The fixed-wing aircraft used by NACA were crashed under their own power by running them into earthen embankments sloped at various angles to give the desired impact conditions.

In the AvCIR tests, helicopters were suspended from the boom of a moving crane and dropped on a target from a height of 30 feet at forward speeds up to 30 miles per hour.

The type of aircraft used in the 20 tests, the conditions under which they were crashed, and the floor accelerations measured during the experiments are shown in Table 2.

A review of the data presented in Table 2 reveals that the magnitudes of the accelerations in both the longitudinal and vertical directions were generally higher in the helicopter tests than in the fixed-wing tests. The durations of the acceleration pulses were longer in the case of the fixed-wing tests, since the total change in velocity for the fixed-wing tests was equal to or greater than that for the rotary-wing experiments. In both instances, the test conditions yielded crashes believed to be potentially survivable; although the tests conducted with the two types of aircraft are not directly comparable, the damage sustained by both aircraft types was comparable and the accidents' conditions were typical of the aircraft types involved.

The higher vertical accelerations obtained at the floor level in the helicopter tests are expected to occur often in accidents and are associated with the operating characteristics of these aircraft and with their unique structural configuration. During helicopter accidents, vertical velocities are generally predominant; and this, in combination with the relatively small amount of crushable structure between the floor and the bottom of the aircraft, results in high vertical accelerations at the floor. Most of the fixed-wing aircraft on which crash accelerations data are available had a greater depth of crushable structure between the floor and the bottom of the fuselage than was available in the corresponding helicopters tested. The crushing of this structure resulted in a more gradual rate of reduction in velocity at floor level, i.e., deceleration. Obviously, design changes of either or both types of aircraft could ultimately change this situation.

On the basis of the foregoing analysis of "accident" data together with the preceding study of human tolerance limits, the rotary-wing aircraft apparently poses the most serious problem in providing the desired crash protection for crew seat occupants because of the "low" human tolerance to vertical deceleration and the "high" vertical accelerations associated with helicopters.

Upon examination of the published acceleration data obtained from the experimental crash tests, it was found that pulse shapes which usually occur are similar to those shown in Figure 11; that is, they may be classified as (A) triangular, (B) half sine wave, or (C) half sine wave with a superimposed triangular peak.

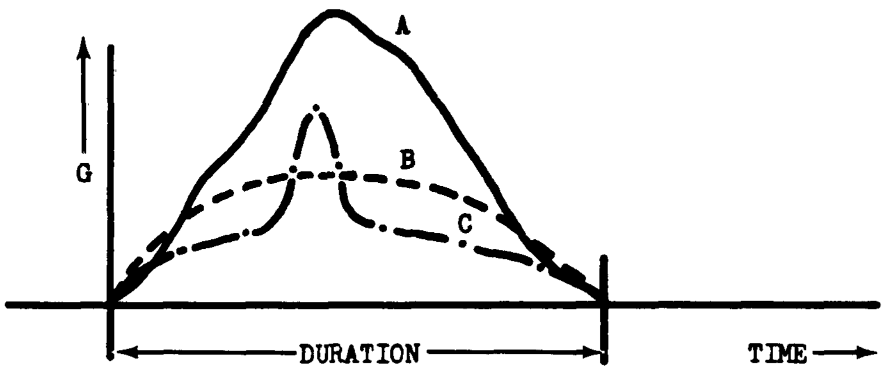


Figure 11. General Pulse Shapes Occurring in Typical Accidents.

Human tolerance data have, by contrast, been based upon a trapezoidal pulse shape in which the duration of the plateau (interval for which a constant level of acceleration was endured) is generally called the "duration." This nomenclature is illustrated in Figure 12.

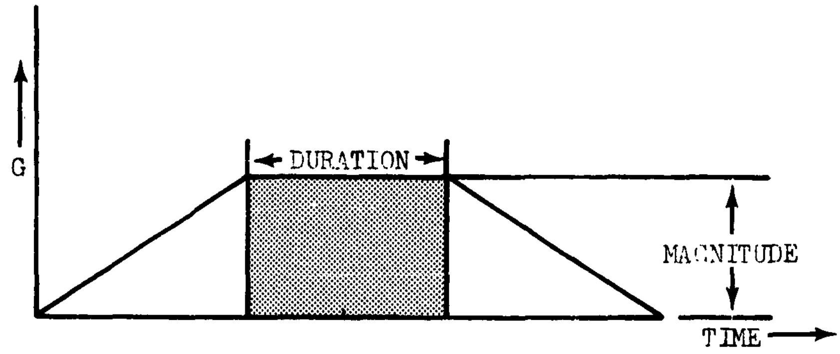


Figure 12. Pulse Shapes Used in Evaluating Human Tolerance.

In order to establish a basis for comparison of human tolerance limits with crash test data, the acceleration records obtained in the helicopter crash tests were divided into segments. The durations of the various plateau levels, as shown in Figure 13, were then established.

1

TABLE 2

SUMMARY OF FULL-SCALE CRASH TEST - FLOOR ACCELERATION DATA

Line Item No.	Type Aircraft	Impact Angle (degrees)	Aircraft Attitude (degrees)	Impact Velocity (m.p.h.)	Location (in. from nose)	ACCELERATIONS LONGITUDINAL Peak Mag. (G)	Time of Occur. (sec.)	Pulse Dur.*	ACCELERATIONS VERTICAL Peak Mag. (G)	Time of Occur. (sec.)	Pulse Dur.*	References
1	Piper J-3	55	55	42	Under Rear Seat	26.5	0.040	0.23	9	0.06	0.02	5
2	Piper J-3	55	55	47	Under Rear Seat	32.5	0.039	0.18	13	0.08	0.04	5
3	Piper J-3	55	55	60	Under Rear Seat	33.5	0.121	0.23	--	--	--	5
4	Fighter Navy FH-1	18	18	112	Cockpit Floor	20	0.06	0.18	--	--	--	1
5	Fighter Navy FH-1	22	22	112	Cockpit Floor	30	0.065	0.18	30 55	0.06 0.285	0.10 0.05	1
6	Fighter Navy FH-1	27	27	112	Cockpit Floor	140	0.065	0.09	--	--	--	1
7	Fighter Navy FH-1	4 (Ground Loop)	4 (Ground Loop)	112	Cockpit Floor	8	2.33	0.10	--	--	--	1
8	Fighter Navy FH-1	Cart Wheel 30° roll	Cart Wheel 30° roll	112	Cockpit Floor	9	0.135	--	15	2.2	0.03	1
9	C-46	5	5	81	270	2.5	0.190	0.33	2.5	0.265	0.35	13
10	C-46	15	15	93	250	10	0.120	0.22	15	0.095	0.18	13
					360	11	0.122	0.22	10	0.075	0.18	
					[illegible]	[illegible]	[illegible]	[illegible]				

10	C-46	15	15	93	250	10	0.120	0.22	15	0.095	0.18	13
					360	11	0.122	0.22	10	0.075	0.18	
					485	7	0.125	0.22	10	0.150	0.18	
					680	9	0.125	0.22	8	0.170	0.18	
11	C-46	29	29	97	185	20	0.145	0.23	25	0.175	0.21	13
					335	22	0.145	0.23	18	0.135	0.21	
					490	20	0.150	0.23	12.5	0.160	0.21	
					685	17	0.155	0.23	10	0.195	0.21	
12	Lodestar	12 (Ground Loop)	12 (Ground Loop)	87	243	3.5	0.265	0.12	9	0.275	0.09	13
					312	3.5	0.260	0.12	9	0.275	0.09	
				63	243	7	1.653	0.13	40	1.653	0.13	
					312	7	1.680	0.13	28	1.680	0.13	
13	Lodestar	16	16	109	243	15	0.195	0.25	18	0.180	0.22	13
					312	13	0.185	0.25	16	0.215	0.22	
14	C-82	4	4	95	Long. 138 Vert. 140	6	0.150	0.17	12	0.30	0.17	13
15	C-82	16	16	91	Long. 340 Vert. 541	15	0.07	0.10	10	0.30	0.07	13
16	H-25 **	45	0	42	60	45	0.11	0.07	115	0.105	0.03	20
					105	36	0.09	0.07	61	0.095	0.06	
17	HUP-2 **	48	0	39	60	44	0.17	0.13	234	0.13	0.03	22
					105	26	.11	0.13	125	0.12	0.045	
18	HUP-2 **	56	0	35	60	40	0.14	0.13	200	0.12	0.03	23
					105	20	0.13	0.13	188	0.115	0.06	
19	H-13	50	0	38	40	150	0.065	0.03	273	0.06	0.03	24
20	H-13	49	0	38	40	175	0.035	0.02	230	0.03	--	24

* The acceleration records obtained at floor level in the crash tests of line items No. 16 through 20 were generally composed of a series of successive individual pulses. The durations given in this table represent the total interval during which the primary decelerations occurred.

**The fuselage geometry of these aircraft are identical. The H-25 is an Air Force designation and the HUP-2 is a Navy designation.

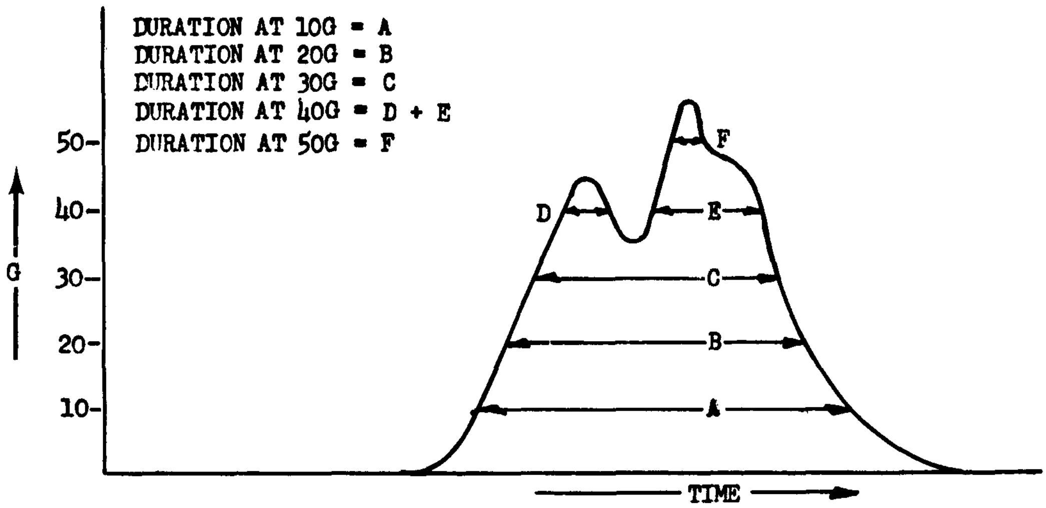


Figure 13. Subdivision of Crash Pulse Acceleration Levels.

A summary of these data is presented in Tables 3 through 7.

TABLE 3

H-25A CRASH TEST CONDUCTED 22 OCTOBER 1960 (T-1)

Location and Plane of Measurement	Magnitude and Duration of Acceleration										Remarks
	10G	20G	30G	40G	50G	60G	70G	80G	90G	100G	Peak G
Cockpit Floor - Long.	.032	.013	.004	.001+							45
Cockpit Floor - Vert.	.022	.018	.014	.012	.009	.007	.006	.005	.004	.003	115
Cabin Floor - Long.	.04	.03	.01	.007	.005	.001					61
Cabin Floor - Vert.	.05	.03	.01	.007	.004						61
Pilot Pelvic - Long.	.017	.010									25
Pilot Pelvic - Vert.	.045	.040	.008	.005	.003						60
Side Passenger Chest - Long.	.15										9
Side Passenger Chest - Vert.	.025	.008	.005	.003	.002						56

TABLE 4
HUP-2 CRASH TEST CONDUCTED 14 JUNE 1961 (T-2)

Location and Plane of Measurement	Magnitude and Duration of Acceleration 10G	20G	30G	40G	50G	60G	70G	80G	90G	100G	Remarks Peak G
Cockpit Floor - Long.	.040	.016	.004	.002							44
Cockpit Floor - Vert.	.016	.014	.011	.009	.008	.007	.0065	.006	.005	.004	234
Cabin Floor - Long.	.044	.04									27
Cabin Floor - Vert.	.026	.010	.008	.007	.0065	.006	.0055	.005	.004	.003	125
Pilot Pelvic - Long.	.05	.02									2 Peaks- 50
Pilot Pelvic - Vert.	.035	.03	.025	.02	.015						55
Side Passenger Pelvic - Long.	.03	.01									25
Side Passenger Pelvic - Vert.	.06	.02									25
Rear Passenger Pelvic - Long.	.015										15
Rear Passenger Pelvic - Vert.	.05	.03	.02	.01							45

TABLE 5
H-13D CRASH TEST CONDUCTED 17 JUNE 1961 (T-3)

Location and Plane of Measurement	Magnitude and Duration of Acceleration 10G	20G	30G	40G	50G	60G	70G	80G	90G	100G	Remarks Peak G
Cockpit Floor - Long.	.014	.012	.010	.008	.006	.0055	.005	.0045	.004	.003	150
Cockpit Floor - Vert.	.01	.006	.0055	.005	.0045	.004	.0035	.003	.0025	.002	273
Pilot Pelvic - Long.	.02	.015	.012	.01	.004	.001					55
Pilot Pelvic - Vert.	.034	.025	.02	.015	.014	.01	.009	.007	.003		99

TABLE 6
HUP-2 CRASH TEST CONDUCTED 9 AUGUST 1961 (T-4)

Location and Plane of Measurement	Magnitude and Duration of Acceleration 10G	20G	30G	40G	50G	60G	70G	80G	90G	100G	Remarks Peak G
Cockpit Floor-Long.	.040	.01									40
Cockpit Floor-Vert.	.012	.011	.010	.009	.0065	.006	.0055	.005	.004	.003	200
Cabin Floor-Long.	.015										15
Cabin Floor-Vert.	.03	.02	.015	.01	.008	.006	.005	.003	.002	.001	188
Pilot Pelvic-Long.	.02	.013									30
Pilot Pelvic-Vert.	.035	.025	.023	.02	.01	.006	.003				75
Copilot Pelvic-Long.	.01	.004	.002								35
Copilot Pelvic-Vert.	.065	.043	.02	.001							45
Floor Pass. Pelvic-Long.	.02	.01	.007	.005	.004	.003	.002				80
Floor Pass. Pelvic-Vert.	.03	.015	.012	.009	.007	.005	.004	.002			82+
Side Facing Pass. Pelvic-Long.	.035	.02	.009				(AvCIR Experimental Seat)				40
Side Facing Pass. Pelvic-Vert.	.06	.019	.01	.003			(AvCIR Experimental Seat)				42
Rear Pass. Pelvic-Long.	.015										18
Rear Pass. Pelvic-Vert.	.50	.03	.02	.012	.009	.003					63

TABLE 7
H-13D CRASH TEST CONDUCTED 3 AUGUST 1961 (T-5)

Location and Plane of Measurement	Magnitude and Duration of Acceleration 10G	20G	30G	40G	50G	60G	70G	80G	90G	100G	Remarks Peak G
Cockpit Floor - Long.	.017	.007	.0055	.005	.0045	.004	.0035	.003	.0025	.002	175
Cockpit Floor - Vert.	.030	.015	.010	.007	.0055	.005	.0045	.004	.0035	.003	230
Pilot Pelvic - Long.	.04	.01	.005	.001							42
Pilot Pelvic - Vert.	.027	.02	.017	.015	.014	.007					65
Copilot Pelvic-Long.	.025	.013	.003								32
Copilot Pelvic-Vert.	.03	.02	.015	.01	.009	.007	.005	.003	.002		95

Selected sets of data from the AvCIR helicopter tests (Tables 3 and 6) have been superimposed on the human tolerance curves for longitudinal (spineward) and vertical (headward) accelerations, resulting in Figures 14, 15, and 16.*

Two points are immediately evident: (a) the longitudinal accelerations occurring in the crash tests at floor level and also in the pelvic and chest regions of the dummy "occupants" are generally below the voluntary human tolerance level, while (b) the vertical accelerations are often above both the voluntary and minor injury levels. An investigation of Tables 4, 5, and 7 readily shows that similar results will be obtained for the data presented therein.

An examination of Tables 3 through 7 shows that only two longitudinal accelerations, other than at floor level, exceeded the voluntary tolerance level of 45G. One was recorded in the pelvic region of a dummy seated on a cushion on the floor directly behind the copilot seat (T-4); the second, in the pilot pelvic region (T-3). Five similar measurements did not exceed 25G. This would indicate that the selection of a crew seat design load of 45G for 0.1 second in the longitudinal direction is a reasonable target. If the seat were also designed to fail progressively beyond these values, protection could be provided up to the maximum accelerations anticipated in most potentially survivable accidents.

An examination of the curves shown in Figures 15 and 16 for the vertical (headward) acceleration indicates that this direction of loading poses the most serious problem. In almost every instance, the accelerations measured at the floor and in the pelvic regions of the dummies exceeded, by a considerable margin, the limits of voluntary human exposure and the limits upon which current ejection seats are designed. Figure 17 illustrates the order of magnitudes of the vertical acceleration pulses recorded in five crash tests of H-25, HUP-2, and H-13D helicopters.

Because it may be difficult to reduce the floor accelerations without serious weight penalties, it appears that some form of energy absorption must be utilized to reduce the vertical acceleration on the

* This method of comparison of human tolerance with actual crash test data has no direct mathematical basis; however, for short duration pulses (0 to .1 second) where the total ΔV is of primary concern, it is obviously conservative with respect to predicting injury.

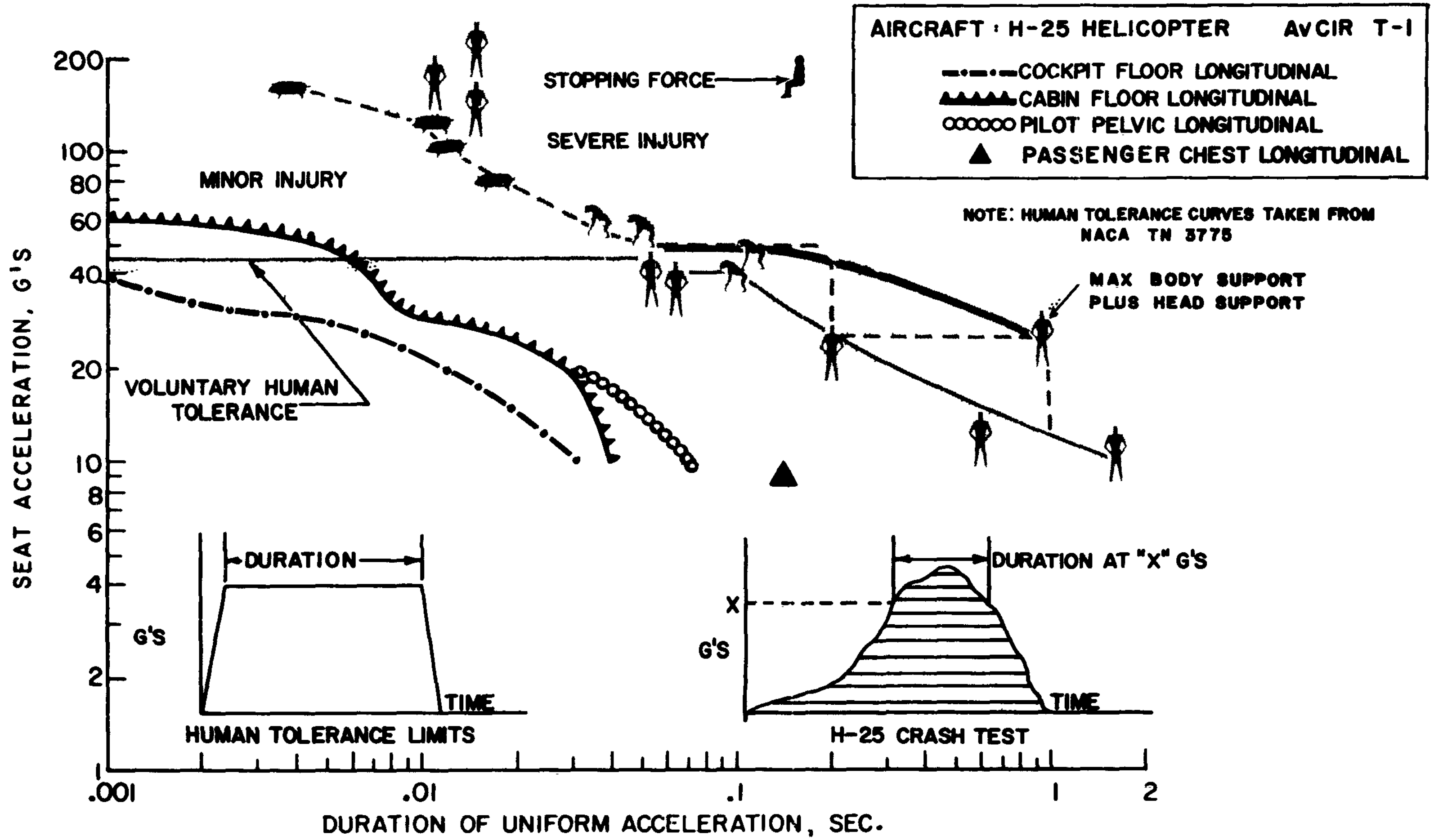


Figure 14. Comparison of Crash Test Data With Human Tolerance to Acceleration Perpendicular to the Spine With Maximum Body Support.

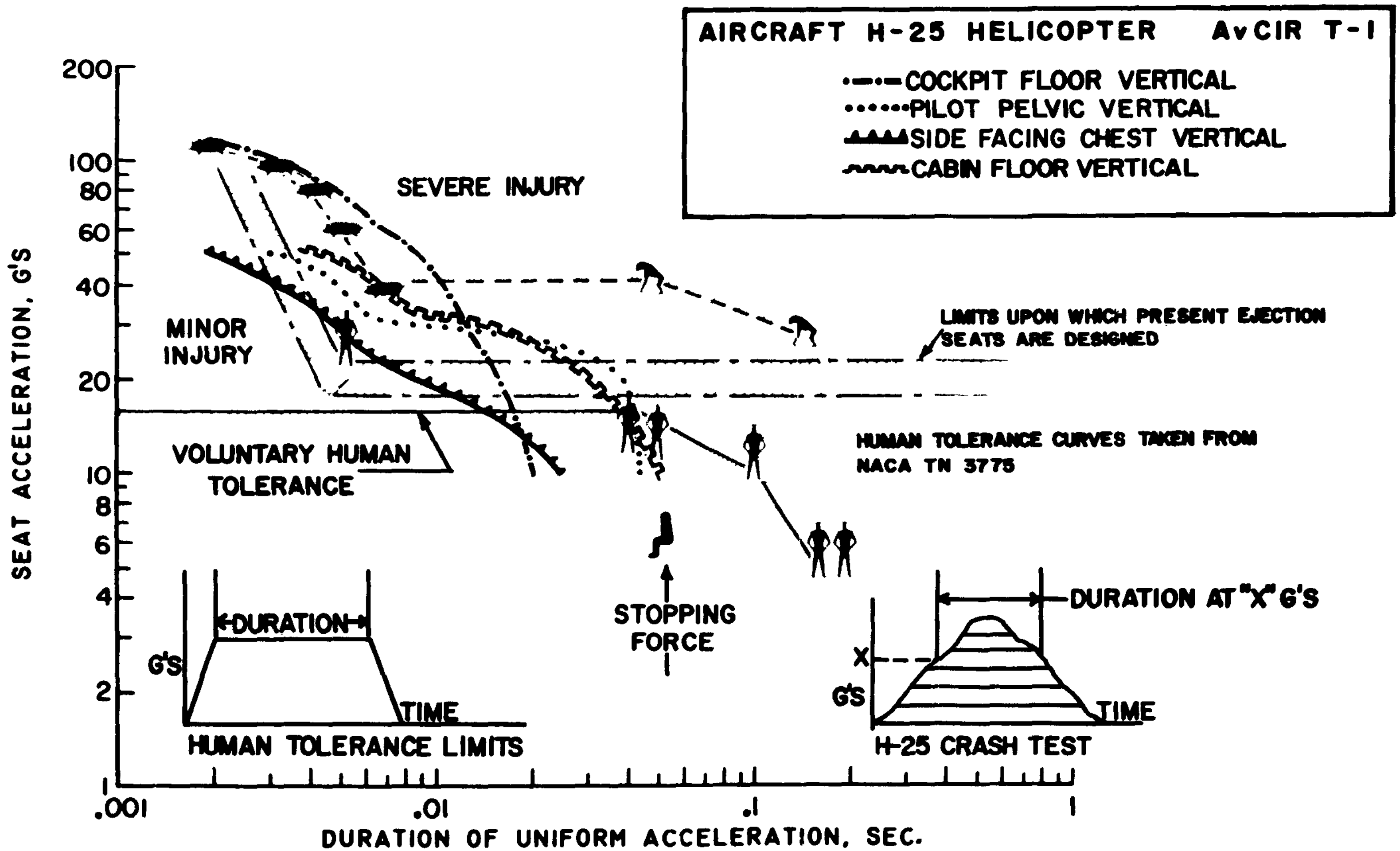


Figure 15. Comparison of Crash Test Data With Human Tolerance to Acceleration Parallel to Spine With Lap Belt and Shoulder Harness.

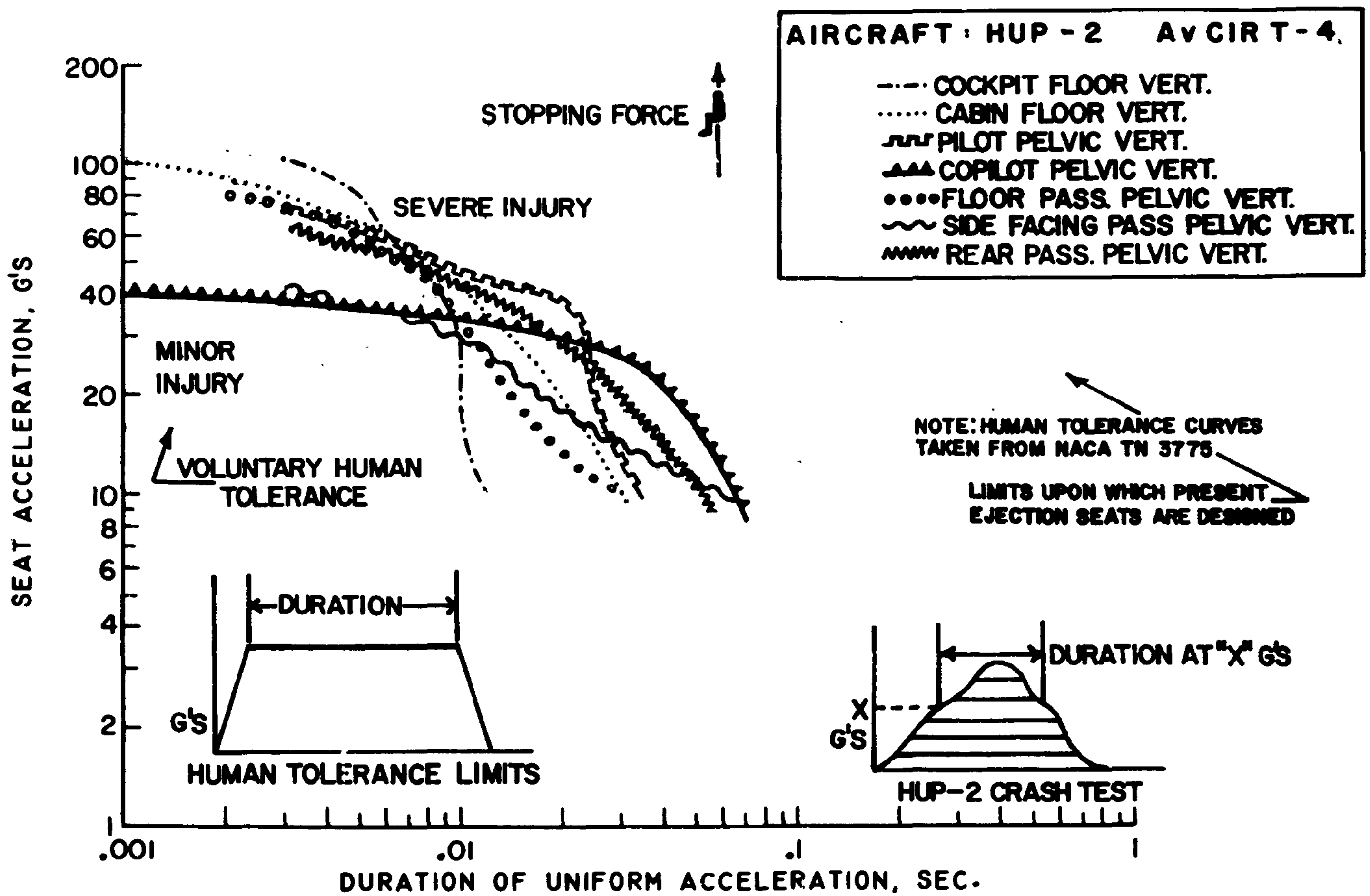


Figure 16. Comparison of Crash Test Data With Human Tolerance to Acceleration Parallel to Spine With Lap Belt and Shoulder Harness.

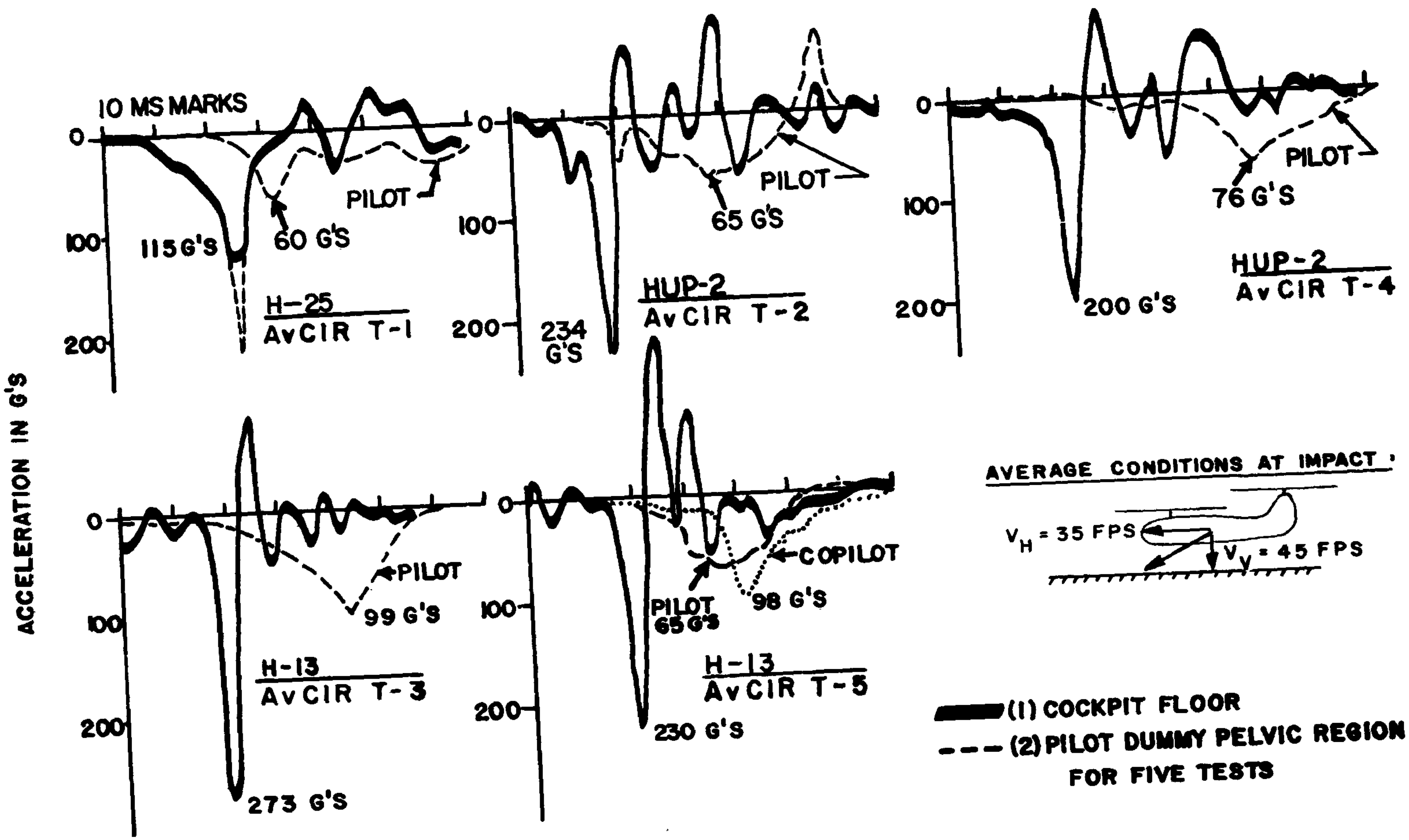


Figure 17. Vertical Accelerations Occurring in Five Helicopter Crash Tests.

occupants to a tolerable level. Since human tolerance to acceleration in this direction is estimated to be approximately 25G, the seat must be designed with an energy absorption system to prevent the accelerations experienced by the occupant from exceeding this value.

Tables 5 and 7 give the floor and pelvic measurements obtained from the two H-13 helicopters. The conditions indicated are somewhat more severe than in the case of the H-25 and HUP-2 aircraft. This is due to the fact that (1) the seats are more rigid than those used in the larger aircraft and (2) the H-13 has much less overall deformable structure between the bottom surface of the aircraft and the seat pan. *

As a final check on the fixed-wing crash data, the peak magnitudes and total pulse duration data points were plotted on the human tolerance curves in Figures 18 and 19. In the longitudinal (spineward) direction, all data points fell below the voluntary exposure curve. In the vertical (headward) direction, several points exceeded the voluntary exposure curves; however, it is felt that the load factors suggested above for the helicopter situation would adequately resolve the fixed-wing problem.

* The deformation of the landing gear and its support structure produced almost no measurable acceleration at floor level in the five helicopter tests conducted by AvCIR.

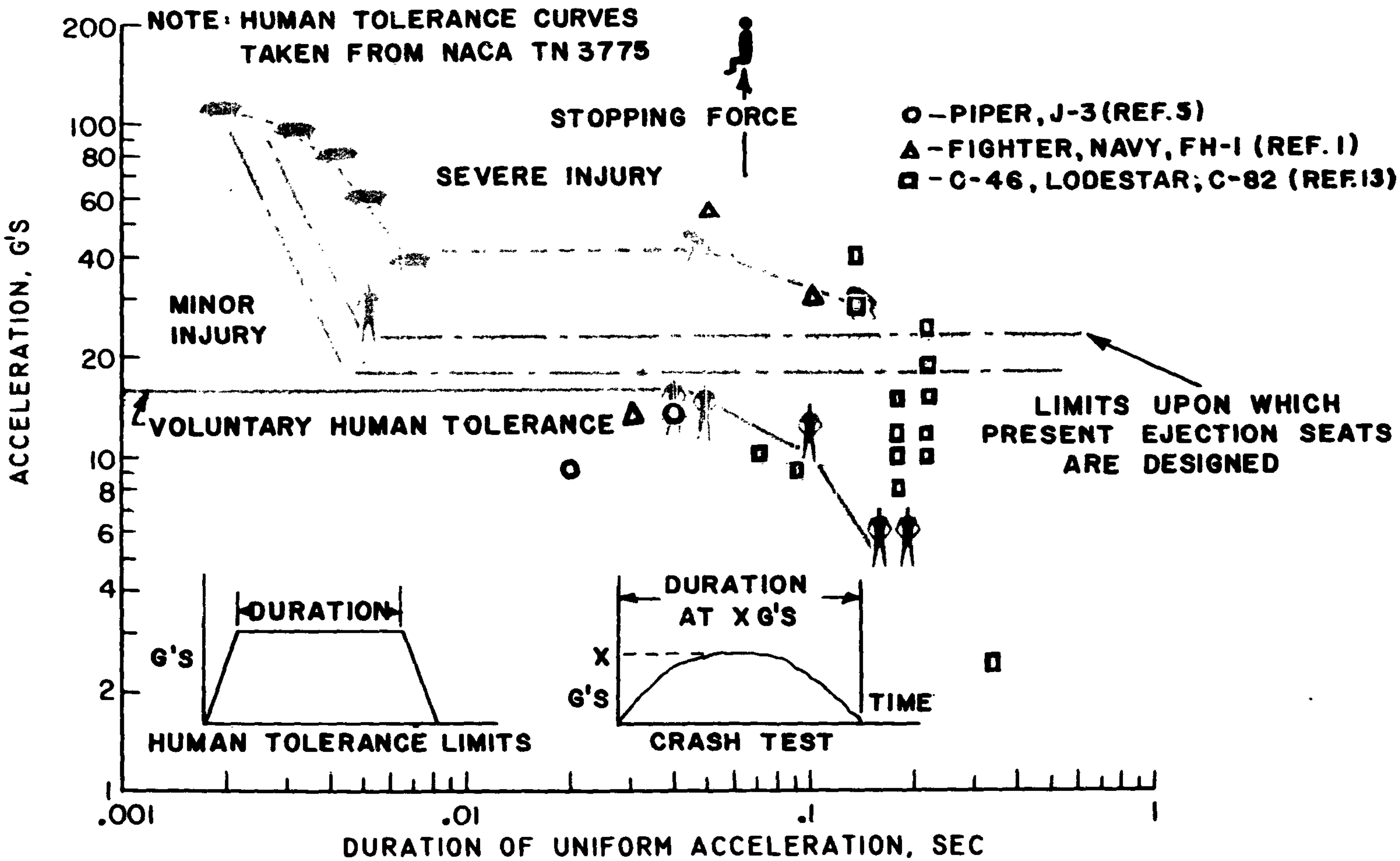


Figure 18. Fixed-Wing Floor Accelerations - Peak Magnitude Versus Total Pulse Duration Compared With Human Tolerance to Acceleration Perpendicular to the Spine.

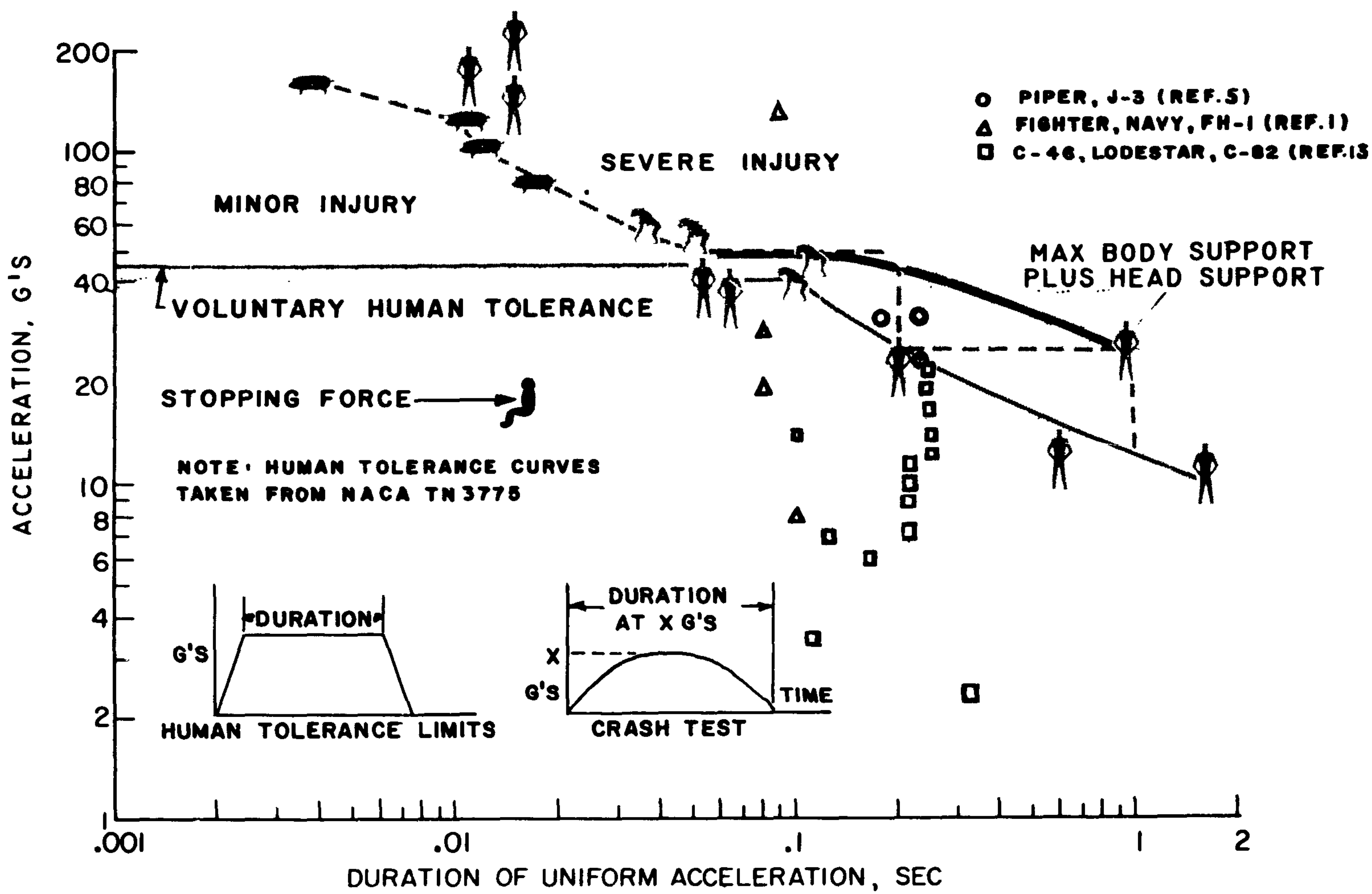


Figure 19. Fixed-Wing Floor Accelerations - Peak Magnitude Versus Total Pulse Duration Compared With Human Tolerance to Acceleration Parallel to the Spine.

COMPENDIUM

CONCLUSIONS

After comparing the crash test data with the limits of human tolerance to transverse, lateral, and vertical (headward) decelerations, it is concluded that the crew seat acceleration design values, selected on the basis of human tolerance alone (25G for 0.20 second and 45G for 0.10 second in the transverse and lateral directions and 25G for 0.10 second in the vertical direction), are near the optimum.

However, it must be clearly understood that the installation of a rigid seat with a vertical design load factor of "25G" would not satisfy the requirements demanded, particularly for helicopters. Referring to Figure 17, it will be readily seen that the vertical accelerations in excess of 25G will occur at the floor level even in accidents involving moderate (40 feet per second) rates of descent. It is quite probable that even lower vertical velocities would still give peak accelerations in excess of 25G. Obviously, a seat of conventional design, even though having a load factor of 25G, would be expected to fail when subjected to such loads.

To investigate the feasibility of developing a system to reduce, for example, 100 to 200G, which can be expected at floor level, to 25G on the occupant, it is assumed that a permanently deformable "massless cushion" having a rectangular stress-strain curve is placed between the bottom of the seat pan and the floor. There is no physical requirement that an actual "cushion" as such be used. Let the maximum usable strain for the "cushion" be ϵ_m, as illustrated in Figure 20. Such stress-strain curves are typical of foamed or honeycombed materials and can readily be realized in mechanical systems.

The acceleration of the torso mass of the occupant can be assumed to follow that of the airframe* until the acceleration reaches the

* In this simple analysis, internal dynamic amplification due to the elasticity of the body is neglected. Many subjects have experienced the 25G maximum proposed without fatal injury and, in fact, with few injuries. Further, the dynamic properties of the deceleration system proposed (massless cushion or spring of zero constant beyond the design load) do not permit dynamic amplification of force on the body as a whole due to overshoot, provided, of course, that the usable energy absorption range for the system is not exceeded.

design value, G_m (Figure 21). (This has been shown to be approximately true in actual tests.)[14, 23] To give the most severe condition, it is assumed here that G_m is reached in a short time interval and, thus, before appreciable reduction in the vertical velocity of the occupant has occurred. The respective acceleration pulses are shown in Figure 21.

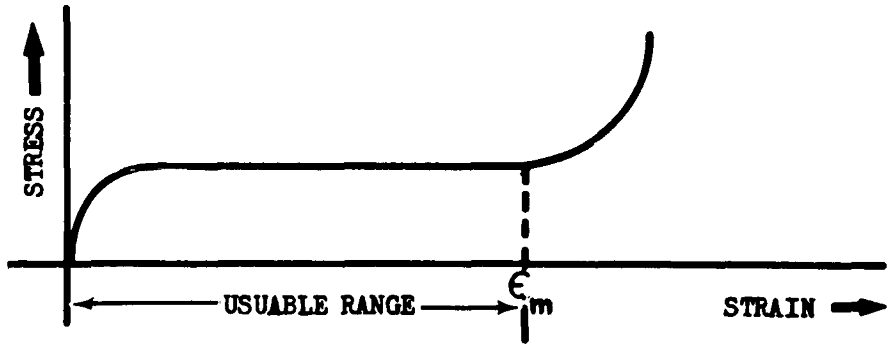


Figure 20. Assumed Stress-Strain Relation for Energy Absorber.

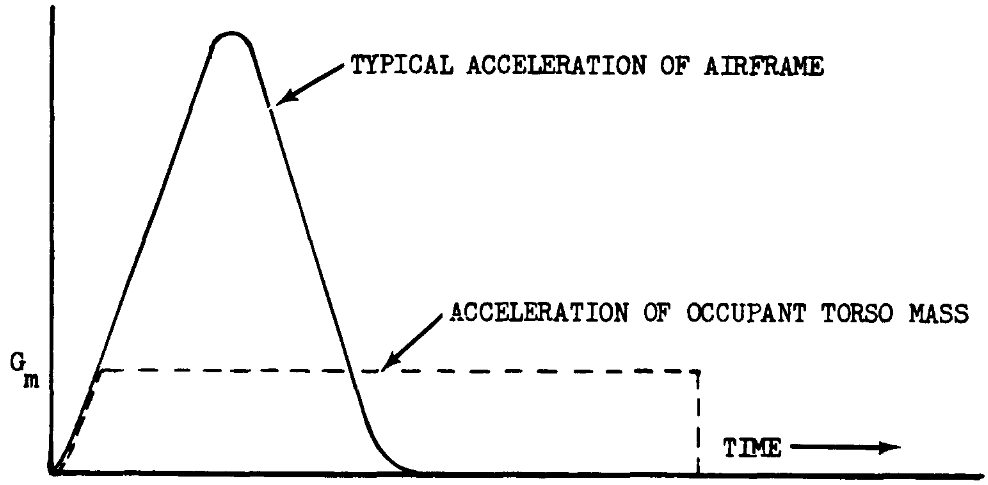


Figure 21. Assumed Acceleration of Floor and Occupant.

Subject to the above assumption, the following relationships hold:

$$Vi^2 = 2AS = 2gG_m S \qquad (1)$$

$$S = \epsilon_m H + D_s \qquad (2)$$

Where:

V_i = Velocity at impact ---- ft./sec.

A = gG_m = Design acceleration for seat system --- ft./sec.

G_m = Design Acceleration ---- G's

g = 32.2 ft./sec.^{2}

S = Stopping Distance ---- ft.

ϵ_m = Maximum usable strain ---- percent

D_s = Effective deformation in aircraft structure --- ft.

H = Cushion thickness (or length of mechanical energy absorber) ----- ft.

Eliminating "S" in equations (1) and (2) gives:

$$H = \frac{1}{\epsilon_m}\left[\frac{V_i^2}{2gG_m} - D_s\right] \text{ ----(3)}$$

This equation is plotted in Figure 22.

As a control or check point, the result of a test conducted by AvCIR during one of the HUP-2 drops is superimposed on Figure 22. In the test, a copilot dummy, supported on 14 inches of paper honeycomb at V_i = 43 ft./sec., gave experimental values of G_m = 35 and ϵ = 50 percent. Figure 22 shows that a theoretical cushion thickness of 1.3 feet (15.6 inches) would be required to maintain 35G to 50 percent strain. This satisfactorily close agreement between experimental and theoretical values indicates the reliability of equation 3 and Figure 22.

An examination of Figure 22 will immediately show that with vertical impact velocities of V_i equal to 30 to 50 ft./sec., ϵ_m = 80 percent, G_m = 25G, and D_s = 3 inches*, vertical travel or deformation of the "seat system" must be of the order of 8 to 24 inches. Such deformation is attainable or approachable if the 15 inches of space below the normal seat is <u>effectively</u> utilized. It is important to recognize that the space alone is worthless and that the seat system must <u>maintain</u> the proposed G_m on the occupant torso during the complete travel. This, then, is the previously mentioned added requirement beyond the specification of a given design load factor.

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* These are realistic values.

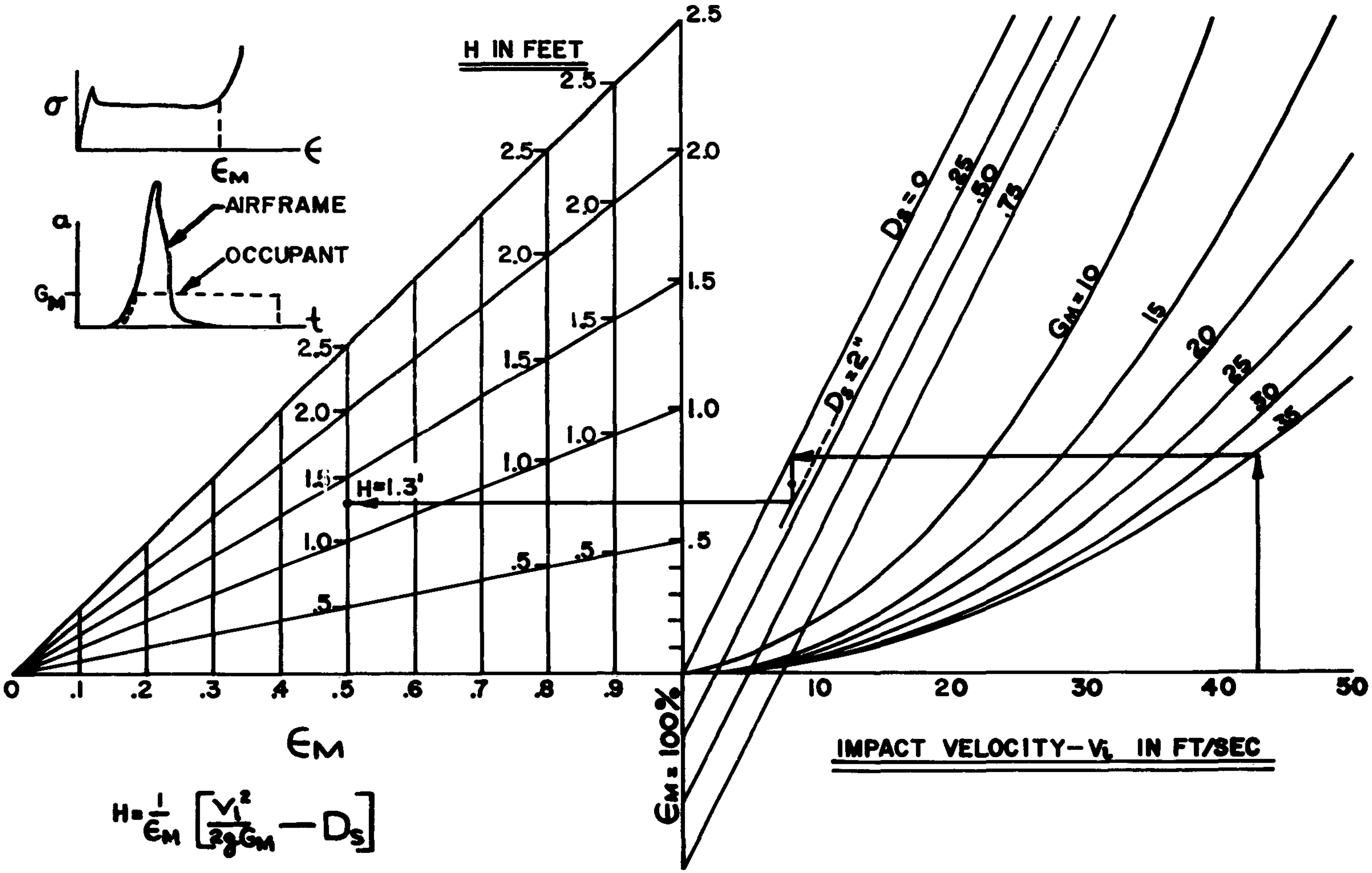

Figure 22. Cushion Thickness H As a Function of G_m, V_i, ϵ_m, D_s.

RECOMMENDATIONS

The following recommendations are presented in light of the foregoing discussions, with particular consideration being given to the experimentally obtained human tolerance data and to the experimentally obtained acceleration environment for light and medium-weight rotary-wing aircraft and C-46 and C-119 cargo transports. They should be considered subject to modifications upon the presentation of new data, but are now believed to be the best compromises possible in view of existing evidence.

It is recommended that the appropriate military specifications applicable to crew seats for rotary-wing aircraft be modified to reflect the following requirements:

1. Longitudinal and Lateral Design Loads. The seat, its support system, and the occupant restraint system should, in combination, be capable of maintaining 25G for 0.20 second and 45G for .1 second in the pelvic region of a suitable dummy having a weight and mass distribution of that of the heaviest occupant expected. (See page 47, "effective mass".)

2. Vertical (headward) Design Loads. The seat, its support system, and the occupant restraint system should, in combination, be capable of continuously maintaining 25G $\pm$ 5G (see page 48, "effect of varying occupant weight) in the pelvic region of the dummy described in paragraph 1, while deforming through at least 12 inches of vertical travel with respect to the airframe and, where possible, up to 15 inches or more of vertical travel. This is an energy absorption requirement, and the mechanism in which the energy is absorbed is unimportant. Through appropriate design, this can conceivably be done by (a) use of mechanical devices, (b) by use of crushable materials, or (c) in the seat structure itself. Whatever the method, the acceleration as a function of displacement should be constant at 25G within the specified 5G tolerance in order that the most effective use can be made of the limited space between seat pan and floor.

   In addition, the seat, its support system, and the occupant restraint system should, in combination, be capable of sustaining 25G for 0.10 second without gross failure.

3. Manner of Loading. The "seat system" should be capable of requirements 1 and 2 both simultaneously and separately without loss of restraint of the occupant during or after impact and in such manner as to maintain alignment of the occupant torso in a normal sitting position. Further, the system, in event of failure due to loads in excess of the design values, should present no projections or cutting edges.

4. Restraint System. The restraint system should include a lap belt, a shoulder harness, and a thigh or crotch strap.

5. Application to Fixed-Wing Aircraft. A considerable amount of impact acceleration data presently exists as a result of the experimental work done by NACA.[9] The experiments conducted, however, were generally directed toward the crash fire problem and were of such a nature that they generally gave relatively low vertical decelerations as compared with known human tolerance to headward pulses. Modifications of either the impact conditions or type of airframe structure would very probably change the end results.

   Military troop transports presently in use and those planned for the future are of the V/STOL types, required to operate on short, unimproved runways. In addition, military troop transports generally do not have large cargo compartments between the floor structure and bottom of the fuselage. It can, therefore, be assumed that the operating procedures required, coupled with the lack of energy absorption structure beneath the floor of the aircraft, will result in accidents in which high vertical accelerations will be imposed upon the occupants of these military transport aircraft. It is, therefore, probable that the requirements set forth in paragraphs 1 through 4, specifically including paragraph 2, apply both to fixed- and rotary-wing aircraft. It is, thus, recommended that, for the present, no distinction with regard to crashworthiness be made in the specifications for crew seats for these two types of aircraft.

OTHER CONSIDERATIONS RELATIVE TO MODIFICATION OF CURRENT MILITARY SPECIFICATIONS

It is obvious that no practical seat restraint system will ever be designed which will permit all occupants of an aircraft to survive all accident situations. However, it is apparently within present technological capabilities to greatly increase the survival rate with acceptable weight and cost penalties. Knowledge and experience in this field, though limited, will grow provided a first step is taken.

The following comments are pertinent to the recommendations of the preceding section. They are presented for information purposes only, and should appear in the final military specifications only after careful consideration of paragraph 2 following.

1. Military Specification. Insofar as possible, the initial specifications for an experimental crew seat meeting the requirements set forth in the preceding section should be as flexible as possible beyond those requirements in order to allow industry to exercise a maximum of ingenuity in the development of a suitable system.

2. Effective Mass Distribution. The recommended design loads appearing in the recommendations, that is,

Longitudinal and Lateral:	45G for 0.10 sec. and 25G for 0.20 sec.
Vertical:	$25G \pm 5G$ for a 12-inch minimum travel
and	25G for 0.10 sec.

are the actual values desired in the pelvic and chest masses of the occupant. In the design of the seat restraint system, the effective mass of the torso of the occupant thus becomes important and must be known. For example, a 200-pound occupant, with feet resting upon the floor, obviously does not apply an effective weight of 200 pounds to the seat. It is estimated that only 75 to 80 percent of the total weight of a normally seated occupant is supported by the seat in a vertical impact of the duration required here. Experimental work is probably needed in this area to determine these values under a variety of conditions.

3. Effect of Varying Occupant Weight. A change in occupant weight from a given standard design value will, unless suitable provisions are designed into the system to allow for variable occupant weight, affect the constant level of deceleration applied to the subject during compression of the energy absorber required in the vertical system for attenuating headward decelerations. Figure 23 illustrates this effect.

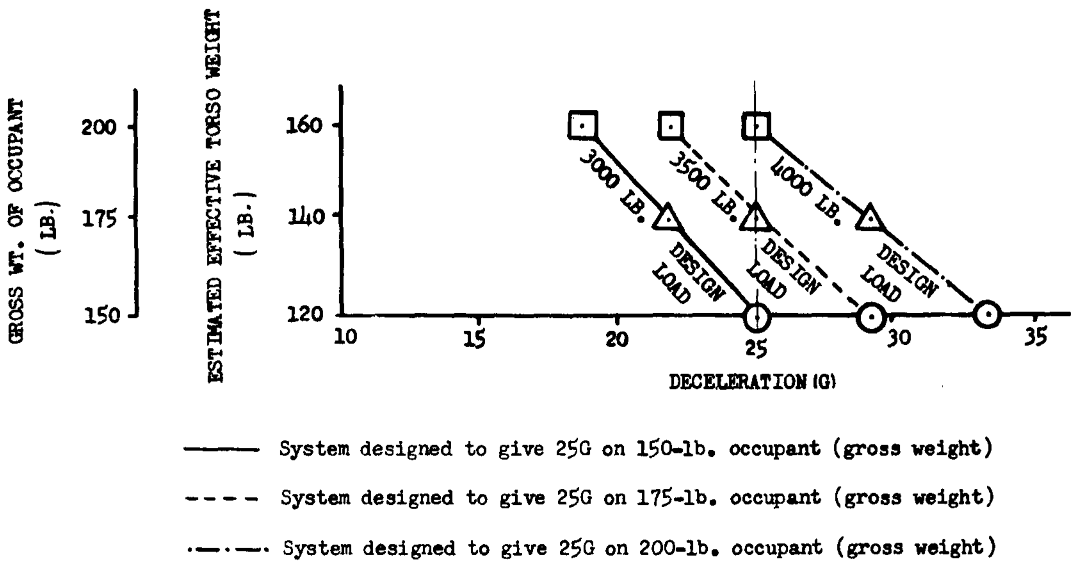

Figure 23. Effect of Varying Occupant Weight on the Constant Level of Deceleration.

A compromise based on statistical average weights will leave the underweight or overweight occupants with reduced protection. Provision for individual adjustment in mechanical systems would be possible.

4. Energy Absorption Requirement. This will be the most difficult requirement to meet, but it is quite probably the most important one for rotary-wing and V/STOL aircraft. It cannot be omitted if maximum protection is to be provided. Problems which will arise and must be solved include:

   a. Maintenance of alignment of occupant during absorber travel.

   b. Maintenance of tight restraint system during absorber travel.

5. Contact Injuries. Delethalization of both the structure of the aircraft and the seat system itself must be given primary consideration for the elimination of injury-producing protrusions.

6. The specification of a dynamic design load condition, i.e., X G's for Y seconds, will require dynamic proof testing for verification of performance and quality control.

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APPENDIX
ACCIDENT EXPERIENCE WITH MILITARY SPECIFICATION CREW SEATS

ACCIDENT A

Description of the Accident

The aircraft involved in this accident, an H-21C, was leading a flight of three aircraft ferrying combat-equipped troops. The intended landing site was situated at the top of a ridge (3,800 feet m.s.l.), approximately six miles from Luray, Virginia, near the Sky Line Drive.[15]

During the crash sequence, the aircraft rolled approximately 90 degrees to the left, scraping down the sides of trees approximately 40 feet in height. The aircraft impacted on its left side. Initial ground contact occurred on the left side of the pilot's compartment, forward of the copilot's seat, with the aircraft in a 3-5 degree nose-down attitude in relation to the ground. After initial impact, the rear section of the aircraft settled with the tail cone wedged between several trees.

Crew Seat Failures

Minor damage was sustained by the supporting structures of the cockpit; however, there was insufficient distortion for any of these members to cause impingement upon or into the occupants.

The most significant damage in the entire cockpit area was the failure of both pilot and copilot seats during the lateral deceleration. Both seat supporting structures failed, permitting the pilot and copilot to be thrown violently to the left. Figures 2 and 3 in the basic report show the seat supporting structures and the failure points.

The complete failure of the seats from their supporting assemblies rendered the shoulder harnesses and the seat belts of both the pilot and the copilot ineffective.

ACCIDENT B

Description of the Accident

A U. S. Army HU-1A Bell helicopter crashed while participating in a field exercise on the Fort Bragg Military Reservation on 20 August 1962.[16]

The pilot, having entered the downwind leg for the intended landing site, felt the aircraft settle and immediately noticed a drop in motor r.p.m. while at an altitude of approximately 200 feet. He immediately lowered the nose to maintain rotor r.p.m. and committed the aircraft to a forced landing.

Crew Seat Failures

At principal impact, the floor and lower seat frame were distorted, due to high vertical forces and penetration of the floor by a tree stump. Because of the longitudinal velocity caused by the whipping action of the fuselage, the pilot apparently slid down and forward, deforming the forward lip of the seat pan and popping the rivets along the right side. As a result of the force applied to the seat by the pilot, and the distortion of the lower seat frame, the seat ripped free from the frame and was thrown forward and to the right out of the aircraft. Figure 5 in the basic report is a view of the lower seat frame still attached to the floor.

The occupant of the copilot seat apparently also slid downward and forward at principal impact, causing distortion of the forward seat pan lip in the same manner as the pilot's seat. The longitudinal force applied by the occupant of the copilot seat at principal impact caused the rear seat support members to fail, permitting the seat to pivot forward and wedge the occupant head-first into the torque pedal well. Figure 4 in the basic report illustrates the portion of the copilot's seat frame remaining attached to the floor after removal of the occupant.

ACCIDENT C

Description of the Accident

A U. S. Army HU-1 Bell helicopter crashed while on a practice flight 3 miles north of Hanchey AAF, Dale County, Alabama, at 1150 on 4 March 1960.[21]

During a climbing right turn with approximately 60 knots indicated airspeed and about 250 feet above the ground, the pilot thought he smelled something burning. He reached up with his left hand to the overhead panel and turned off the aircraft heater, at the same time looking up to make sure he had the right switch. As a normal reaction to the outstretching of his left arm, he involuntarily applied a small amount of right forward cyclic, not realizing it because of the servo flight control system and the absence of forced trim. This put the aircraft in a nose-low attitude, increasing the airspeed and allowing the rate of descent to build up to approximately 1,300 feet per minute. It also turned the aircraft downwind and picked up a 12-knot tail wind. By the time the pilot got his tension back and realized the attitude that the aircraft was in, he was descending rapidly into a patch of trees which he reported were only about 50 feet away when he first saw them. His ground speed was in the neighborhood of 95 knots, and with the rate of descent near 1,300 feet per minute, the aircraft had no time to respond to his control before hitting the trees and the ground.

Crew Seat Failure

Figure 6 in the basic report is a rear view of the crew seat failure in Accident C. The rear attachment failed at the casting (arrow 1) while the front failure occurred at a drill point in the front cross tube (arrow 2).

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Report is made of results of careful analysis of military crew seat deficiencies. Criteria are (Cont'd.)

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